6.0 Tsunamis & Seiches

6.1 Why Focus on Tsunami & Seiche Hazard Mitigation?

Tsunamis are sea waves (sometimes referred to as tidal waves) of local or distant origin that occur as a result of large-scale seafloor displacement.

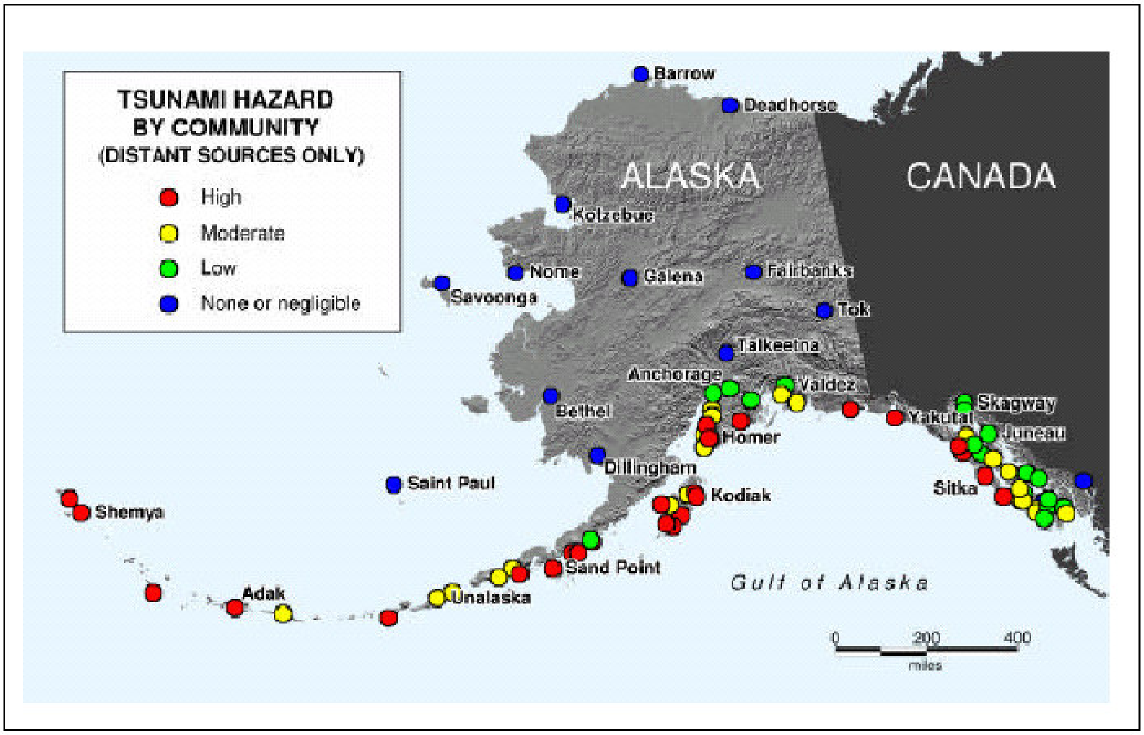

Figure 6-1. Alaska Tsunami Hazard by Community.

Typically, seismic activity, volcanic activity or landslides (above or below sea in origin) generate the uplift or drop in the ocean floor. Within Alaska, the most tsunami-vulnerable regions are the low-lying coastal zones along the Gulf of Alaska and the Pacific Ocean, including much of the Kenai Peninsula Borough shoreline.

The potential for tsunamis to cause tremendous damage to the KPB is well documented. On March 27th, 1964, the city of Seward was devastated by a series of waves generated by a 9.2[1] magnitude earthquake. With four active volcanoes and a high potential for earthquakes of magnitude 6.0 or greater, Borough coastal communities (tsunamis are generated by earthquakes with a magnitude of 7.0 or greater[2]).

1 U.S. Department of Commerce, National Science Services Administration, U.S. Coast and Geodetic Survey. 1964. United States Earthquakes.

2 Oregon Department of Geology and Mineral Industries. 2001. Tsunami Warning Systems and Procedures: Guidance of Local Officials. Special Paper 35 prepared for the National Tsunami Hazard Mitigation Program.

Coastal areas with the greatest tsunami risk are generally less than 50 feet above sea level and within one mile of the shoreline[1]. There are three primary sources of damage from tsunamis: inundation (the extent the water goes over the land), wave impact (both incoming and receding currents) and coastal erosion.

The direction or path, the wave energy, the coastal configuration and the offshore topography influence the terminal height (or run-up) of the wave and therefore the potential for damage[2]. As tsunamis reach the coastal shoals wave velocity decreases but wave height increases. Waves can reach heights of more than 100 feet and strike coastal areas with extraordinary force.

A seiche is a wave that oscillates in partially or totally enclosed bodies of water and can last from a few minutes to a few hours. The resulting effect is similar to bathtub water sloshing repeatedly from side to side. The reverberating water can continue to cause damage until the activity subsides. Events such as earthquakes, landslides, avalanches, high winds or changes in atmospheric pressure may trigger seiches. Similar to locally-generated tsunamis, the onset of the first wave from the causal event may take only a few minutes, giving virtually no warning.

6.2 Types of Tsunamis

The four primary types of tsunamis that could impact the KPB include:

- tele-tsunami
- volcanic tsunami
- seismically generated tsunami
- landslide-generated tsunami

Tele-Tsunami

Tele-tsunami is the term used when a tsunami travels 1,000 kilometers or more from its source. In many cases, tele-tsunamis allow for sufficient warning time and evacuation. According to the State All-Hazard Mitigation Plan, Alaska's coastal areas are believed to be at relatively low risk of experiencing high magnitude tele-tsunamis[3]. To date, no damage from tele-tsunamis has been recorded within the Kenai Peninsula Borough.

Magnitude	***Height (ft)***
-2 to -1	<1.0 to 2.5
-1 to 0	2.5 to 4.9
0 to 1	4.9 to 9.9
1 to 2	9.9 to 19.7
2 to 3	19.7 to 34.2
3 to 4	34.2 to 79.0
4 to 5	79.0 to >105.0

Table 6-1. Tsunami Magnitude and Height Relationships.

[1] Federal Emergency Management Agency. 2004. Fact Sheet: Tsunamis
[2] Pararas-Carayannis, G. 2004. The Tsunami Page. www.drgeorgepc.com/TsunamiFAQ.html.
[3] Alaska Division of Homeland Security and Emergency Management (DHS&EM). State Hazard Mitigation Plan. DMA 2000 - Updated September 2004.

Volcanic Tsunamis

Volcanoes that are situated in the sea or near the coast can initiate tsunamis by generating earthquakes, pyroclastic flows, submarine explosions, debris avalanches, caldera collapse, pyroclastic surges, lahars and airwaves from explosions, and lava avalanches into the sea[1]. Factors governing tsunami magnitude include the volume of debris that enters the sea, the velocity of the avalanche and the water depth in the run-out zone[2].

There are five active volcanoes within the KPB on the west side of Cook Inlet: Fourpeaked, Augustine, Iliamna, Redoubt and Mount Spurr (Figure 6-2).

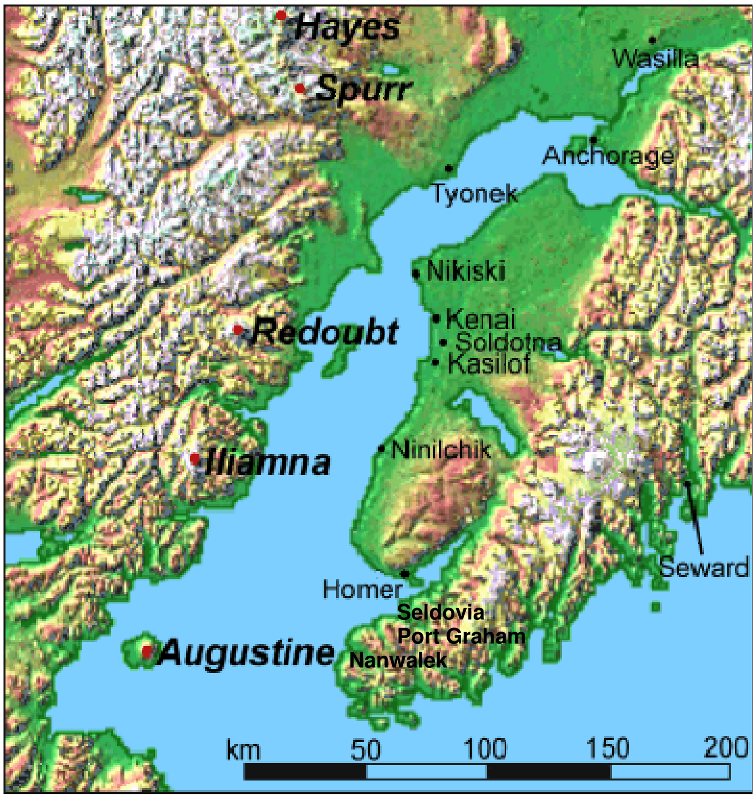

Figure 6-2. Volcanoes in the Cook Inlet Region[3].

Located at the southern end of Cook Inlet approximately 90 kilometers west of Nanwalek, Augustine Volcano has the potential to generate tsunamis. A number of anecdotal records indicate that an 1883 eruption of Mt. Augustine caused a

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1 Waythomas, C.F. and R.B. Waitt. 1998. Preliminary Volcano-Hazard Assessment For Augustine Volcano, Alaska. U.S. Geological Survey, Open File Report 98-106.

2 Ibid.

3 Modified from Ray Sterner, Johns Hopkins University, Applied Physics Laboratory (Copyright 1998).

series of tsunami waves to strike the villages of Nanwalek and Port Graham[1]. Information suggests wave heights of 20 to 30 feet hit the communities within 30 minutes of the eruption. Low tide at the time of the tsunami was reported as the reason for minimal damage.

Seismically-Generated Local Tsunamis

Although in recent years most of the seismically-generated local tsunamis have occurred along the Aleutian Arc, seismic activity is common in the KPB (see Section 4.0 Earthquakes) and is often associated with the active volcanoes. An island in Cook Inlet, Augustine has high probability of generating tsunamis waves that could impact communities in lower Cook Inlet.

Landslide-Generated Tsunamis

Submarine and surface landslides can generate large waves. Surface landslides have greater associated kinetic energy than submarine landslides so they typically trigger larger tsunamis. Earthquakes often trigger multiple landslides and landslide-generated tsunamis. Submarine landslides occur more readily at low tide when water-saturated sediments are exposed and lack the support of the water. Additional loading from human activities, such as warehouses, canneries and freight yards can increase a delta's instability. In Alaska, landslide events usually occur in heavily glaciated areas such as Resurrection Bay, Kachemak Bay and Prince William Sound.

Landslide-generated tsunamis are often the deadliest, because they quickly follow the triggering event with little to no warning. The Seward harbor was seriously damaged in 1964 when a large section of waterfront slid into Resurrection Bay during the Good Friday earthquake. The landslide-generated waves were followed a short time later by quake-generated tsunami waves. The city of Homer was impacted by a landslide-generated tsunami when a large debris slide near the Grewingk Glacier sent a wave of water across Kachemak Bay[2].

Seiches

A seiche is a wave that oscillates in partially or totally enclosed bodies of water. Seiches can last from a few minutes to a few hours as a result of an earthquake, surface or submarine landslide or atmospheric disturbance. The resulting effect is similar to bathtub water sloshing repeatedly from side to side. The reverberating water will continue to cause damage until the activity subsides. Similar to a local tsunami, the onset of the first wave may happen in only minutes, giving virtually no time for evacuation or warnings.

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[1] Montgomery Watson and Parker Horn Company. 2001. Flood Hazard Mitigation Plan, Port Graham, Alaska, Kenai Peninsula Borough, Feb. 2001. Waythomas, C.F. and R.B. Waitt. 1998. Preliminary Volcano-Hazard Assessment For Augustine Volcano, Alaska. U.S. Geological Survey, Open File Report 98-106.

[2] City of Homer All-Hazard Mitigation Plan (Annex A).

In Alaska, seiches are commonly generated by the collapse of deltas into deep glacial lakes. They may also be associated with deltas built through time by alluvial streams, which typically consist of unconsolidated gravel, rock and debris. Within the Kenai Peninsula Borough, slide-induced waves have occurred on Kenai, Tustumena and Skilak Lakes[1].

6.3 Historical Tsunami Events

1883 Tsunami

Records indicate that Augustine erupted in 1883, and a large debris avalanche slid into Cook Inlet, causing a series of four 15- to 30-foot waves to strike the village of English Bay (now known as Nanwalek)[2]. An entry in the Alaska Commercial Company trading post daily log (University of Alaska Archives), indicated that wave heights were six meters above the "usual" level[3]. Nearby, Port Graham residents also reported several 15-foot waves striking within a half-hour of the eruption. Because the tide was low at the time, damage was minor but boats were swept into the harbor and several residences were flooded[4]. If a similar event occurred during high tide, damage to low-lying areas in the communities of Seldovia, Port Graham, Nanwalek and Homer could be substantial[5].

1964 Tsunami

The 1964 earthquake triggered several tsunamis: one major tectonic tsunami and about 20 local submarine and surface landslide tsunamis. The major tsunami hit south-central Alaska between 20 and 45 minutes after the earthquake. The local tsunamis struck between two and five minutes after the quake and caused a majority of the fatalities. Overall, the tsunamis were responsible for more than 90% of the earthquake related deaths, killing 106 Alaskans as well as 17 people in California and Oregon[6].

In Seward, the earthquake caused a 1,070 meter section of the Seward waterfront to collapse into Resurrection Bay (Figure 6-3). The landslide generated a 30-foot local tsunami that destroyed most of the facilities near the waterfront, including a fuel tank farm, which started the first of many fires.

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1 Foster, H. and T. Karlstrom. 1967. The Alaska Earthquake, March 27, 1964: Region Effects. Ground Breakage and Associated Effects in the Cook Inlet, Alaska, Resulting from the March 27, 1964, Earthquake. Geological Survey Professional Paper 543-F. United State Department of the Interior, Washington, D.C.; McCulloch, D. 1966. Slide-Induced Waves, Seiching and Ground Fracturing Caused by the Earthquake of March 27, 1964, at Kenai Lake, Alaska. Geological Survey Professional Paper 543-A. United State Department of the Interior, Washington, D. C.

2 Waythomas, C.F. and R.B. Waitt. 1998. Preliminary Volcano-Hazard Assessment For Augustine Volcano, Alaska. U.S. Geological Survey, Open File Report 98-106.

3 Ibid.

4 Montgomery Watson and Parker Horn Company. 2001. Flood Hazard Mitigation Plan, Port Graham, Alaska, Kenai Peninsula Borough. March 2001.

5 Troshina, E.N., 1996. Tsunami waves generated by Mt. St. Augustine Volcano, Alaska: Fairbanks, University of Alaska, M.S.thesis, 84pp in Waythomas, C.F. and R.B. Waitt. 1998. Preliminary Volcano-Hazard Assessment For Augustine Volcano, Alaska. U.S. Geological Survey, Open File Report 98-106.

6 Sokolowski, T. 2004. The Great Alaskan Earthquake & Tsunamis of 1964. West Coast & Alaska Tsunami Warning Center, Palmer, Alaska.

Smaller tsunamis then spread the burning fuel floating on the water surface and started another fire at the Texaco Petroleum tank farm further inland[1].
In the small boat harbor, landslide-induced waves collapsed the dock and sank 30 fishing boats and 40 pleasure craft. The railroad yards were also heavily damaged, as were freight cars in the marshalling yards. The waves struck with sufficient force to move a 120-ton locomotive 100 feet and sweep a 75-ton locomotive 300 feet inland.

About twenty minutes after the first local tsunami hit the Seward waterfront, a 40-foot earthquake-generated wave struck. This wave carried a wall of flaming oil into Seward, destroying and setting fire to a large section of town. All told, about 95% of Seward's industrial base was lost and 15% of the town's residential properties were totally destroyed or heavily damaged. There were 12 fatalities, 200 injuries[2] and approximately $14 million in damage[3].

1 KPB All-Hazard Plan, Annex E: City of Seward. 2004. All-Hazard Mitigation Plan.
2 Alaska Division of Homeland Security and Emergency Management (DHS&EM). State Hazard Mitigation Plan. DMA 2000 - Updated September 2004.
3 Sokolowski, T. 2004. The Great Alaskan Earthquake & Tsunamis of 1964. West Coast & Alaska Tsunami Warning Center, Palmer, Alaska.

Figure 6-3. Tsunami Damage to the City of Seward Waterfront Following the March 27,1964 Earthquake[1].

Although 10- to 30-foot quake generated tsunami waves were also reported in Homer, Seldovia, Port Graham and Nanwalek[2], there were no fatalities and much less damage. The primary damage in Homer involved two to six feet of earthquake-induced subsidence along the five-mile-long Homer Spit road. As a result, 70 percent of the Spit flooded during the following autumn high tides. In Seldovia as well as other coastal areas, many boats and some waterfronts were damaged[3]. The land in much of Seldovia subsided four feet, necessitating the rebuilding and relocation of much of the village.[4]

6.4 Tsunami & Seiche Risk Assessment

Tsunami vulnerability is greater when coastal communities have beaches that open to the ocean or are located near bay entrances, tidal flats and shores of

[1] Source: John Combs Seward Part 2 website: www.alaskarails.org/historical/earthquake/earthquake-seward2.html.

[2] United States Army Corps of Engineers, May 1968. Coastal Engineering Research Center, Technical Memorandum No. 25, The Tsunami of the Alaskan Earthquake, 1964, Engineering Evaluation ***in*** FEMA. 1999. Flood Insurance Study, Kenai Peninsula Borough, Alaska (revised). Community Number 020012.

[3] Sokolowski, T. 2004. The Great Alaskan Earthquake & Tsunamis of 1964. West Coast & Alaska Tsunami Warning Center, Palmer, Alaska [wcatwc.arh.noaa.gov/64quake.htm].

[4] Suleimani, E.N., et al., Tsunami Hazard Maps of the Homer and Seldovia Areas, Alaska. State of Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, 2005

coastal rivers. Within the KPB, the most significant threat is from local tsunamis generated in Resurrection Bay, Alaska Pacific waters and Cook Inlet. Communities at primary risk include Seward, Homer, Seldovia, Port Graham and Nanwalek.

The entire KPB lies within Zone 4 (highest earthquake hazard potential) of the former Uniform Building Code[1]. Zone 4 is susceptible to earthquakes of magnitude greater than 6.0 in which major structural damage could occur. A strong earthquake that lasts more than 20 seconds can also generate a tsunami[2]. See Section 4.0 for additional KPB earthquake information.

According to the KPB Emergency Response Plan[3], coastal communities in the East and South Zones are highly vulnerable to tsunami events, which have a moderate probability of occurring. Residents of North and Central Zone coastal communities are moderately vulnerable to tsunamis, although the probability of occurrence is low due to the shallow depth of upper Cook Inlet and the lack of substantial submarine structures.

Table 6-2. Population and Facility Tsunami Hazard Vulnerabilities for the Kenai Peninsula Borough[4].

Zone	Population within vulnerability zone*	Property that may be damaged	Probability of occurrence
North	2,000	Structures, vehicles and equipment, port and harbor facilities, transportation facilities, airports	Low
Central	2,000		Low
East	7,000		Moderate
South	7,500		Moderate

* Numbers are for “worst case” occurrence in summer.

Tsunamis have the potential to damage structures, vehicles, boats, equipment, harbor and transportation facilities. The probability of simultaneous emergencies following a tsunami is rated as high in the KPB Emergency Response Plan[5]. Associated events include industrial/technological emergencies (resulting from fire, explosions and hazardous materials incidents), disruption of vital services (such as water, sewer, power, gas and transportation) and damage and disturbance to emergency response facilities and resources.

1 Pers. comm., Rod Combellick, Acting Director, Alaska Division of Geological and Geophysical Surveys. Fairbanks, Alaska, 2004.
2 National Disaster Education Coalition. 1999. Tsunami. In: *Talking About Disaster: Guide for Standard Messages.* Washington, D.C. Available at http://www.fema.gov/pdf/rrr/talkdiz/tsunami.pdf.
3 Pinkston Enterprises. 2004. Kenai Peninsula Borough Emergency Operations Plan. Prepared for the Office of Emergency Management, Kenai Peninsula Borough, Soldotna, Alaska.
4 Pinkston Enterprises. 2004. Kenai Peninsula Borough Emergency Operations Plan. Prepared for the Office of Emergency Management, Kenai Peninsula Borough, Soldotna, Alaska.
5 Ibid.

6.4.1 Populations and Facilities at Risk

Overall

Depending on the epicenter and magnitude, an earthquake-generated tsunami could result in significant damage to KPB coastal communities. The tsunami inundation maps for the communities of Homer, Seldovia and Seward provide a tool to more accurately assess the number of people and development that is at risk in those communities. Risk assessments for the other unmapped communities, at least in the near term, will be based on available historical or estimated information.

The DHS&EM (formerly Alaska Division of Emergency Services), with input from an interagency committee, established a statewide priority list for tsunami inundation mapping. As part of this effort, maps for Homer and Seldovia have been finalized[1] and Seward is scheduled to receive maps in early 2010. The tsunami maps can be used to more accurately predict the number of people and development at risk, as well as assist with land use and emergency response planning.

Due to resource limitations, the smaller KPB coastal communities are currently not scheduled for tsunami mapping. Without inundation maps, communities must rely on historical or estimated information for land use and evacuation route planning.

North Zone

Coastal areas with potential tsunami risk in the North Zone begin at the north side of the mouth of the Kenai River and continue north up the coast, including the west side of Cook Inlet. Due to the relatively shallow depth of upper Cook Inlet and the substantial distance from areas to the south with significantly higher risk, the upper Inlet is believed to have low tsunami risk[2].

Central Zone

The areas of concern in the Central Zone begin at the south side of the mouth of the Kenai River and continue south to Clam Gulch. Due to the relatively shallow depth of upper Cook Inlet and the substantial distance from the lower end of Cook Inlet, the Central Zone is believed to have a low tsunami risk.

East Zone

Surface and submarine landslides could hit both the east and west shores of Resurrection Bay, which increases Seward's vulnerability to both local seiche waves and earthquake generated waves (see Section 6.3 Historical Tsunami Events).

[1] Pers. comm., Rod Combellick, Acting Director, Alaska Division of Geological and Geophysical Surveys. Fairbanks, Alaska, 2004.

[2] Pers. comm., Rod Combellick, Acting Director, Alaska Division of Geological and Geophysical Surveys. Fairbanks, Alaska, 2004; For project status visit [http://www.aeic.alaska.edu/tsunami/index.htm].

South Zone
The South Zone communities are vulnerable to earthquake, volcano and surface and submarine landslide induced tsunamis that originate in Prince William Sound, the Gulf of Alaska and Cook Inlet. Typical peak wave heights from large tsunamis in the Pacific Ocean over the last 80 years have been between 21 and 45 feet at the shoreline. A few waves, however, have been higher locally - as much as 100 feet in a few isolated locations[1].

Tsunamis could impact both the east and west shores of Cook Inlet. Potentially vulnerable communities include Port Graham, Nanwalek, Seldovia, Homer, Anchor Point, Ninilchik and other small communities along the water.

Both Port Graham and Nanwalek are at risk from tsunami damage. As part of their Flood Hazard Mitigation Plan[2] (Annex G), the community of Port Graham used the 100-foot elevation contour to map their potential tsunami hazard zone (Figure 6-4). This map did not take into account site-specific shoaling effects or wave diffraction that may impact water run-up – factors that are included in the interagency-produced inundation maps (described above). According to the Port Graham Flood Mitigation Plan:

Current development is concentrated in the coastal areas, making the community vulnerable to flooding from tsunamis and extreme events. Much of the available land is owned by the Port Graham Village, allowing them to a certain extent to control the development of the community. Future development could occur along existing roads, preventing the need for costly road construction. Duncan Heights Road, Second Street, and A Street could all accommodate additional development. Structures along these roads, while still in the Tsunami Hazard Zone, would be out of immediate danger from storms or coastal erosion. (Annex G, p. 6-1)

[1] Earthquake Education Center. 1996. *Tsunami! How to Survive the Hazard on California's Coast*. Humboldt State University. http://www.wsspc.org/tsunami/CA/CA_survive.html.
[2] Montgomery Watson and Parker Horn Company. 2001. Flood Hazard Mitigation Plan, Port Graham, Alaska, Kenai Peninsula Borough, Feb. 2001.

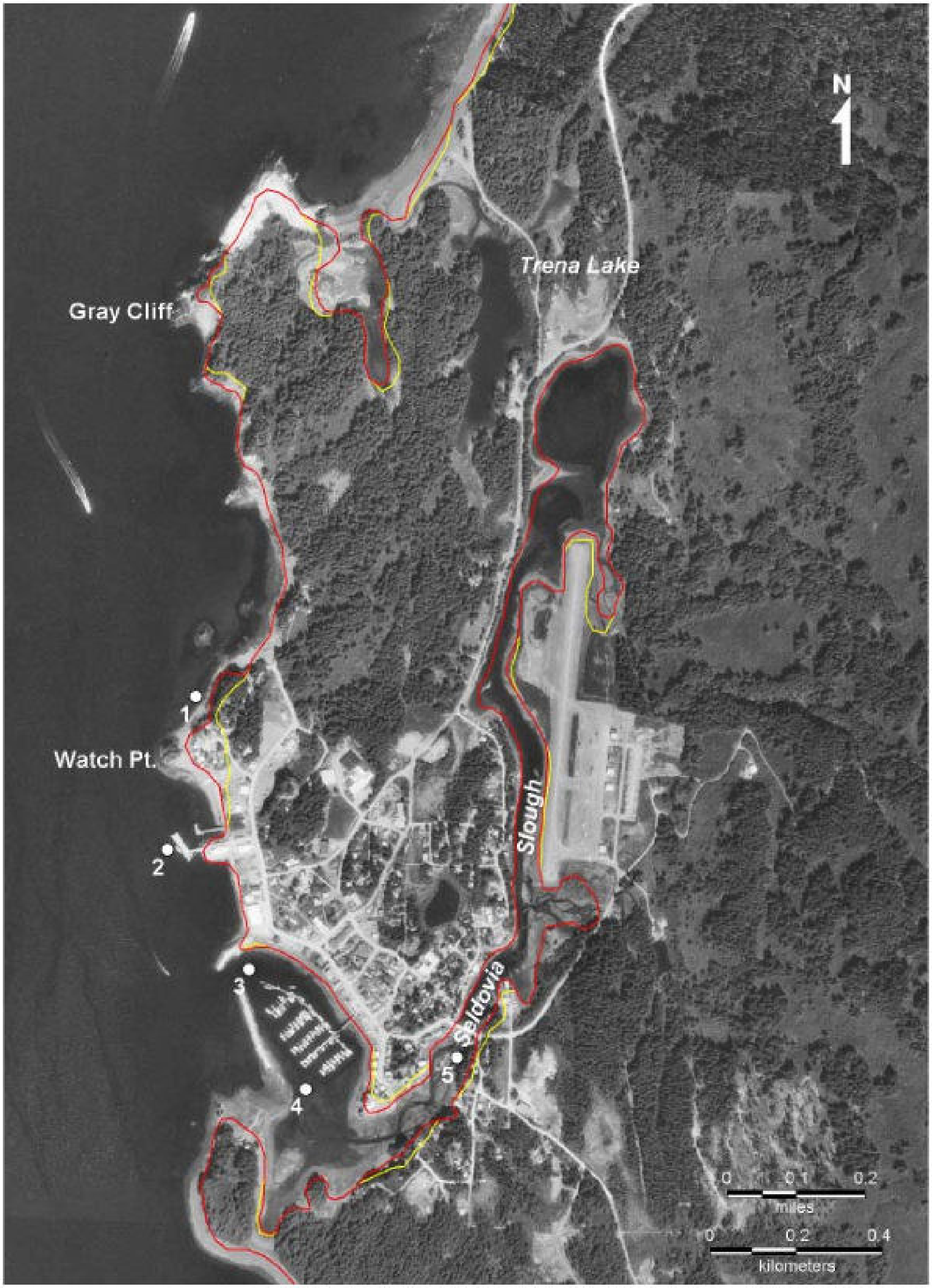


Figure 6-5. Tsunami Hazard Map for Seldovia, Alaska

Figure 6-6. Port Graham Tsunami Hazard Zone[1].

6.5 Tsunami & Seiche Mitigation Goals

Although it is not possible to eliminate the threat that tsunami hazards pose to Borough residents, it is possible to identify ways to reduce vulnerability. To this end, three goals were identified to best serve and protect the Kenai Peninsula Borough from tsunami and seiche related hazards. These goals encompass both

[1] Montgomery Watson and Parker Horn Company. 2001. Flood Hazard Mitigation Plan, Port Graham, Alaska, Kenai Peninsula Borough, Feb. 2001.

agency and individual responsibilities and are the same for all hazards, although mitigation strategies are tailored to the specific nature of each hazard.
All-hazard mitigation goals include:

- protection;
- prevention; and
- education.

6.5.1 Accomplishing KPB Tsunami and Seiche Mitigation Goals

The following are suggested as approaches to further define and accomplish the Borough's long-term tsunami mitigation goals.

- modify the impacts of tsunamis and seiches by assisting individuals and communities to prepare for, respond to and recover from these events;

- Reduce susceptibility to damage and disruption by avoiding hazardous, uneconomic and unwise development in tsunami hazard areas.

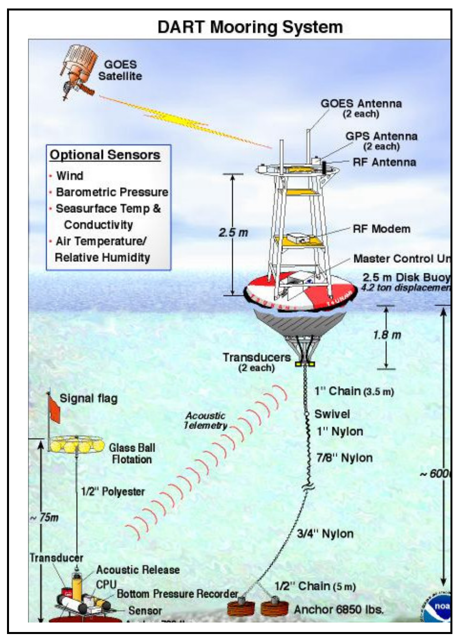
- protect the natural and beneficial values of Peninsula floodplains, coastal areas and water resources;

- Promote positive economic development.

6.5.2 Existing Tsunami & Seiche Mitigation Programs and Activities

6.5.2.1 Deep-Ocean Assessment and Reporting of Tsunamis (DART)

The DART project is a component of the larger U.S. National Tsunami Hazard Mitigation Program (NTHMP). The NTHMP is a comprehensive Federal and State effort to reduce loss of life and property due to tsunami inundation along U.S. coastlines. Cooperating U.S. agencies include NOAA, FEMA, USGS, and the Emergency Management agencies of the five Pacific States: Alaska, California, Hawaii, Oregon and Washington.



The DART project is an ongoing effort to develop and implement early detection and real-time reporting of tsunamis in the open ocean. Project goals are designed to:

- reduce the loss of life and property in U.S. coastal communities; and

- eliminate false alarms and the high economic cost of unnecessary evacuations.

To ensure early detection and acquire information critical to real-time tsunami forecasting, DART stations were sited in regions where destructive tsunamis have been generated in the past. A DART system consists of a seafloor bottom pressure-recording device (BPR) capable of detecting sea surface elevation changes as small as one centimeter, and a moored surface buoy for real-time communication. An acoustic link is used to transmit data from the BPR on the seafloor to the surface buoy. The data are then relayed via a GOES satellite link to ground stations, which modulate and transfer the signals to NOAA Tsunami Warning Centers and the Pacific Marine Environmental Laboratory (PMEL).Tele-tsunami warnings generated by the DART systems are expected to provide more accurate tsunami wave predictions for coastal communities in the Pacific Northwest and Alaska. Several DART stations are located in the central and western Gulf of Alaska and extend westward to the end of the Aleutian Chain.

6.5.2.2 TsunamiReady Program

Based on the NWS StormReady model, the TsunamiReady Program is a National Weather Service (NWS) initiative that promotes public safety and tsunami hazard preparedness. It is a collaborative program that combines the efforts of federal, state and local emergency management agencies, the public, and the NWS tsunami warning system.

In 2002, Seward and Homer became Alaska's first TsunamiReady communities (Figure 6-5). Before a community can be declared tsunami ready, it must meet five guidelines under the categories of communications and coordination, tsunami warning reception, warning dissemination, awareness and program administration[1].

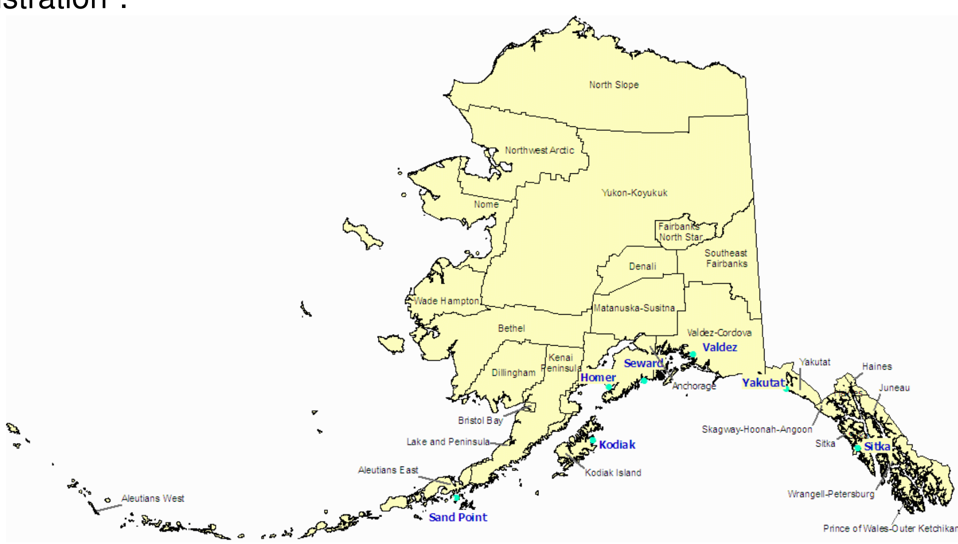


Figure 6-7. Communities in Alaska that Participate in the TsunamiReady Program[2].

1 Guidelines detailed online at www.tsunamiready.noaa.gov/guidelines.htm
2 Image Source: www.tsunamiready.noaa.gov/ts-com/ak-ts.htm.

6.5.2.3 Tsunami Inundation Mapping Program

As part of a larger federal program, Alaska is generating tsunami inundation maps for communities along the Gulf of Alaska. The DHS&EM, in cooperation with the University of Alaska Fairbanks, the Division of Geological and Geophysical Survey, the West Coast and Alaska Tsunami Warning Center, the National Weather Service and NOAA have completed detailed studies to predict tsunami threats for the cities of Homer and Seldovia. The study for Seward is due to be completed in April 2010. With data from these studies, detailed tsunami inundation maps can be generated. The studies and resulting maps will greatly assist the cities with future emergency planning efforts such as delineating evacuation routes. The maps will also be useful for land-use planning and development decisions. These maps will require maintenance and upgrades as new data becomes available and coastal changes occur.

6.5.2.4 West Coast/Alaska Tsunami Warning Center (WC&ATWC)

The WC&ATWC was established in Palmer, Alaska in 1967 as a direct result of the Good Friday earthquake that occurred in Prince William Sound on March 27, 1964. The earthquake alerted state and federal officials to the need for a facility to provide timely and effective tsunami warnings and information for Alaska's coastal areas.

In 1982, the WC&ATWC's area of responsibility (AOR) was enlarged to include California, Oregon, Washington, and British Columbia. In 1996, the responsibility was again expanded to include all Pacific-wide tsunamigenic sources that could affect the California, Oregon, Washington, British Columbia and Alaska coasts.

Tsunami warnings are of two types: regional warnings for tsunamis produced in or near the AOR and warnings for tsunamis generated outside the AOR. Regional warnings are issued within 15 minutes of earthquake origin time and are based solely on seismic data. Warnings are issued for any earthquake in the WC&ATWC's AOR over magnitude 7. Warnings outside the WC&ATWC's AOR are issued after coordination with the Pacific Tsunami Warning Center in Ewa Beach, Hawaii. The warnings are based on seismic data, along with historical tsunami records and recorded tsunami amplitudes from tide gauges.

In addition to evacuation warning messages, the WC&ATWC also provides informational messages for earthquakes that may be felt strongly by local citizens but are not large enough to generate a tsunami. Each year, the WC&ATWC staff responds to more than 250 alarms (an average of five per week). The informational messages are important for preventing needless evacuations since citizens near coastal areas are taught to move to higher ground when earthquakes occur. The WC&ATWC provides the public with critical, correct and timely tsunami information.

6.5.2.5 Tsunami Warning and Environmental Observatory for Alaska (TWEAK)
TWEAK is a program to collect tsunami information and biological and oceanographic data. Its efforts are focused on the following areas:

- tsunami research
- water quality
- ocean productivity
- weather prediction
- education and outreach

The information generated by TWEAK is expected to enhance the productivity and improve utilization of the ocean resources available in Kachemak Bay, Cook Inlet and the Gulf of Alaska.

6.5.2.6 Digital Elevation Mapping for Kenai Peninsula
Digital elevation mapping (DEM) data using LIDAR has been acquired for the Kenai Peninsula and is currently being processed. LIDAR (LIght Detection And Ranging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The Seward area was flown in January 2006 during a snow-free period, and the western Kenai lowlands were flown in the summer of 2008. The data acquired has a resolution of one pixel per four foot square and a vertical accuracy of plus or minus 20 centimeters. No data was acquired for the ice fields or for communities across Kachemak Bay/Cook Inlet.

6.6 Tsunami & Seiche Mitigation Strategies and Implementation Ideas

Tsunami damage associated with the 1883 volcanic eruption and the 1964 earthquake (see 6.3 Historical Tsunami Events) highlight the ongoing vulnerability of KPB coastal communities to this hazard. Though it is not possible to prevent tsunamis and seiches from occurring, both agencies and individuals can participate in mitigation activities to greatly lessen or eliminate damage. Potentially cost-effective ways to offset losses include increasing public awareness of tsunami prone areas, improving and practicing emergency warning and response measures, minimizing non-water dependent development in tsunami runup zones, and implementing measures to help water-based facilities withstand or deflect tsunami wave forces. The mitigation strategies that follow were developed to reduce tsunami-associated loss of life and property while simultaneously fulfilling the overall hazard mitigation plan goals of protection, prevention and education. Additional tsunami mitigation recommendations can be found in the Homer and Seward City Annex Sections.

Strategy 1: Increase public awareness of tsunami and seiche mitigation activities and emergency response.

Implementation Ideas and Action Items

- Continue tsunami education activities for coastal residents (such as development of personal disaster preparedness kits for resident's homes and vehicles).
- Increase public awareness of the All-Hazard Alert and Broadcast (AHAB) siren system and the reverse 911 community notification system (Rapid Notify).
- Maintain the number and visibility of warning signs to alert visitors and residents when entering tsunami hazard areas.
- Continue to ensure that evacuation routes and assembly areas are clearly marked in the event of emergency.
- Coordinate with coastal communities to develop additional evacuation routes.
- Work with local health services, emergency services and American Red Cross officials to identify people with mobility impairments who live or work in tsunami vulnerable areas and develop plans for providing evacuation assistance.

Potential Participants:	Communities of Homer, Seward, Seldovia, Port Graham and Nanwalek, Alaska Division of Homeland Security and Emergency Management, Office of Emergency Management (KPB), Local Emergency Planning Committee
Time Frame:	Ongoing

Strategy 2: Conduct mock tsunami hazard response exercises to identify response vulnerabilities.

Implementation Ideas and Action Items

- Conduct simulated exercises to determine vulnerabilities in emergency response and facilities. This will help identify areas that need further attention, resources and training.

Potential Participants: Office of Emergency Management (KPB), Local Emergency Planning Committee, Tsunami Vulnerable Communities
Time Frame: Ongoing (longer term 2-4 years)

Strategy 3: Enhance tsunami-warning systems in KPB coastal communities.

Implementation Ideas and Action Items

- Evaluate the need for additional tsunami warning systems in coastal communities across the Kenai Peninsula Borough.
- Continue to partner with the NWS to use their all-hazard warning system (weather radio) to initiate alerts and provide KPB area-specific hazard warnings.
- Seek funding to complete tsunami run-up maps for Port Graham and Nanwalek.
- Support ongoing coordination between the incorporated cities, KPB, local utilities and state and federal agencies to promote disaster warning and preparedness planning and training.
- Add a permit liaison position to the KPB Incident Command Structure to coordinate emergency permitting with regulatory agencies during and immediately following disaster events.
- Maintain the revolving flood mitigation fund for the purpose of delivering clean water, sand bags or other critical services or supplies to communities during disaster emergencies.

Potential Participants: National Weather Service, Alaska Division of Homeland Security and Emergency Management, Office of Emergency Management (KPB), Local Emergency Planning Committee, Incorporated Cities within the KPB
Time Frame: Ongoing (longer term 2-4 years)

Strategy 4: Minimize tsunami damage to structures in the Kenai Peninsula Borough.

Land use planning and regulatory steps such as zoning can help limit tsunami damage by reducing or preventing certain types of "non-water-dependent" development in high-risk areas. Risks to coastal development can be minimized in many ways, including: encouraging elevation and bracing of buildings, positioning structures on the highest available ground, using the lower floors as non occupied spaces and encouraging the development of site planning regulations requiring streets and structures to be perpendicular to potential waves so there is less resistance and erosive force. Water-based facilities like ferry terminals and shipping docks should be built to withstand tsunami wave forces.

Implementation Ideas and Action Items

- Use tsunami inundation maps (when available) to assist with land use planning, zoning and permitting decisions and processes.

- Support the development of tsunami inundation maps for all vulnerable KPB coastal communities that haven't yet been mapped.

- Encourage residents to explore building options to make property and structures more resistant to tsunami damage. Options may include such activities as elevating coastal homes, identifying ways to possibly divert water away from coastal structures and implementing sound site planning, building design and construction.

- Require written disclosure of hazard prone areas (such as coastal storm surge - FIRM V Zones, tsunami run-up zones and areas with high erosion potential) when property ownership is transferred.

- Encourage non-participating local communities to join the TsunamiReady program to help them prepare for tsunami events.

- Explore partnerships to provide retrofitting information or classes to homeowners, renters, building professionals and contractors who work or live in tsunami vulnerable locations.

Potential Participants:	National Weather Service, Office of Emergency Management (KPB), Capital Projects Division (KPB), KPB Planning and Floodplain Programs, Local Emergency Planning Commission, Community Schools Program (KPB School District), AK State Division of Homeland Security and Emergency Management, FEMA, Local Construction Companies, Incorporated Cities within the KPB
Time Frame:	Ongoing

6.7 Tsunami & Seiche Resource Directory

Local Resources

Kenai Peninsula Borough Office of Emergency Management (OEM)

KPB/OEM was established to coordinate disaster management response between the Kenai Peninsula Borough, the State of Alaska, FEMA and other municipalities, as well as other response and recovery organizations. OEM has the primary responsibility for overseeing disaster management programs and activities, including mitigation, planning, response and public education.

Contact: Office of Emergency Management
Address: 253 Wilson Lane, Soldotna, AK 99669
Phone: (907) 262-4910
Website: www.borough.kenai.ak.us/emergency

State Resources

State of Alaska, Division of Homeland Security and Emergency Management

This agency in part conducts hazard preparedness and mitigation workshops. They also coordinate the State of Alaska's All-Hazard Mitigation Plan. Their community response program works with communities during a crisis as well in recovery and planning phases.

Contact: AK Division of Homeland Security and Emergency Management
Address: P.O. Box 5750, Fort Richardson, AK 99505-5750
Phone: (907) 428-7000 OR (800) 478-2337
Website: www.ak-prepared.com

Alaska Earthquake Information Center

AEIC serves as an integration center for all seismic networks within Alaska and archives and processes data from the Alaska Tsunami Warning Center in Palmer, Alaska and the Alaska Volcano Observatory in Fairbanks and Anchorage.

Contact: Geophysical Institute, University of Alaska Fairbanks
Address: 903 Koyukuk Drive, P.O. Box 757320, Fairbanks, Alaska 99775-7320
Phone: (907) 474-7320
Website: www.aeic.alaska.edu/

Federal Resources

FEMA: Mitigation Division

FEMA's Mitigation Division manages the National Flood Insurance Program and oversees a number of mitigation programs and activities, which provide protection (flood insurance), prevention and partnerships to communities throughout the country.

Contact: FEMA/Region X
Address: 130 228th Street, SW, Bothell, WA 98021
Phone: (425) 487-4600
Website: www.fema.gov/about/regions/regionx/

National Oceanic and Atmospheric Administration (NOAA)

NOAA's historical role has been to predict environmental changes, protect life and property, provide decision makers with reliable scientific information, and foster global environmental stewardship. NOAA supports the West Coast and Alaska Tsunami Warning Center.

Contact: National Oceanic and Atmospheric Administration
Address: 1401 Constitution Avenue, NW, Room 5128, Washington, DC 20230
Phone: (202) 482-6090
Fax: (202) 482-3154
Website: www.noaa.gov

National Weather Service, Alaska Region Headquarters

The National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure, which can be used by other governmental agencies, the private sector, the public, and the global community.

Contact: National Weather Service/ Alaska Region Headquarters
Address: 222 West 7th Avenue #23, Anchorage, AK 99513-7575
Phone: (907) 271-5088 OR 1-800-472-0391 (Alaska Weather Line)
Fax: (907) 271-3711
Website: Alaska: www.arh.noaa.gov/
National: www.nws.noaa.gov/

The National Tsunami Hazard Mitigation Program

The program is designed to reduce the impacts of tsunamis through warning, mitigation and hazard assessment.

Contact: National Tsunami Hazard Mitigation Program
Address: Box 50027, Honolulu, Hawaii 96850-4993
Phone: (808) 541-1657 or 1658
Fax: (808) 541-1678
Website: www.pmel.noaa.gov/tsunami-hazard/

Additional Resources

International Tsunami Information Center (ITIC)

The ITIC is maintained by the U.S. National Oceanic and Atmospheric Administration for the Intergovernmental Oceanographic Commission to mitigate the effects of tsunamis throughout the Pacific.

Contact: International Tsunami Information Center
Address: Box 50027, Honolulu, Hawaii 96850-4993
Phone: (808) 541-1657 or 1658
Fax: (808) 541-1678
Website: www.geophys.washington.edu/tsunami/general/mitigation/itic.html

Public Assistance Debris Management Guide

Federal Emergency Management Agency (July 2000).
The Debris Management Guide was developed to assist local officials in planning, mobilizing, organizing, and controlling large-scale debris removal and disposal operations. Debris management is generally associated with post-disaster recovery. The *Public Assistance Debris Management Guide* is available in hard copy or on the FEMA website.

Contact: FEMA Distribution Center
Address: 130 228th Street, SW, Bothell, WA 98021-9796
Phone: (800) 480-2520
Fax: (425) 487-4622
Website: www.fema.gov/government/grant/pa/demagde.shtm

Alaska Science Forum

The Alaska Science Forum provides information and articles as a public service of the Geophysical Institute, University of Alaska Fairbanks (UAF) in cooperation with the UAF research community.

Contact: Geophysical Institute
Address: 903 Koyukuk Drive, University of AK, Fairbanks, AK 99775-7320
Websites: Geophysical Institute: www.gi.alaska.edu/ OR
www.gi.alaska.edu/ScienceForum/weather.html

National Weather Radio (NWR)

NOAA National Weather Service Weather Radio

NWR is a nationwide network of radio stations broadcasting continuous 24-hour weather information directly from a nearby National Weather Service office. NWR is an “all hazards” radio network, making it a comprehensive weather and emergency information source. NWR also broadcasts warning and post-event information for all types of hazards.

Contact: NOAA, National Weather Service
Office of Climate, Water and Weather Services
Address: 1325 East West Highway, Silver Spring, MD 20910
Website: National: www.nws.noaa.gov/nwr

Contact: NOAA/NWR Anchorage Forecast Office
Address: 6930 Sand Lake Road, Anchorage, AK 99502
Websites: Alaska NWR Locations: www.nws.noaa.gov/nwr/stations.php?State=AK
Anchorage Forecast Office: pafc.arh.noaa.gov/
Phone: 1-800-472-0391 (Alaska Weather Line)

NWS/TsunamiReady Program

Based on the NWS StormReady model, the TsunamiReady Program is a National Weather Service (NWS) initiative that promotes tsunami hazard preparedness to provide consistent and location specific mitigation activities for at-risk communities. This is a collaborative program that combines the efforts of federal, state and local emergency management agencies, the public, and the NWS tsunami warning system.

TsumamiReady guidelines, examples, and applications also may be found on the Internet or by contacting the West Coast and Alaska Tsunami Warning Center.

Contact: West Coast & Alaska Tsunami Warning Center
Address: 910 S. Felton St., Palmer, AK 99645
Phone: (907) 745-4212
Website: www.tsunamiready.noaa.gov/

American Red Cross

The American Red Cross is a volunteer humanitarian organization that provides relief to disaster victims and helps people prevent, prepare for, and respond to emergencies.

Contact: American Red Cross
Address: 235 E. 8th Avenue, Anchorage, AK 99501
Phone: (907) 646-5401
Website: alaska.redcross.org

Publications

Oregon Department of Geology and Mineral Industries. 2001. Tsunami Warning Systems and Procedures: Guidance for Local Officials. Special Paper 35. Available at www.preventionweb.net/english/professional/publications/v.php?id=1474

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